HAWC: Hardware and Calibration

Fermi/HAWC/VERITAS Workshop
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Outline

1) Cherenkov Detectors
2) Laser Calibration System
3) Timing Calibration
4) Charge Calibration

With much support from:
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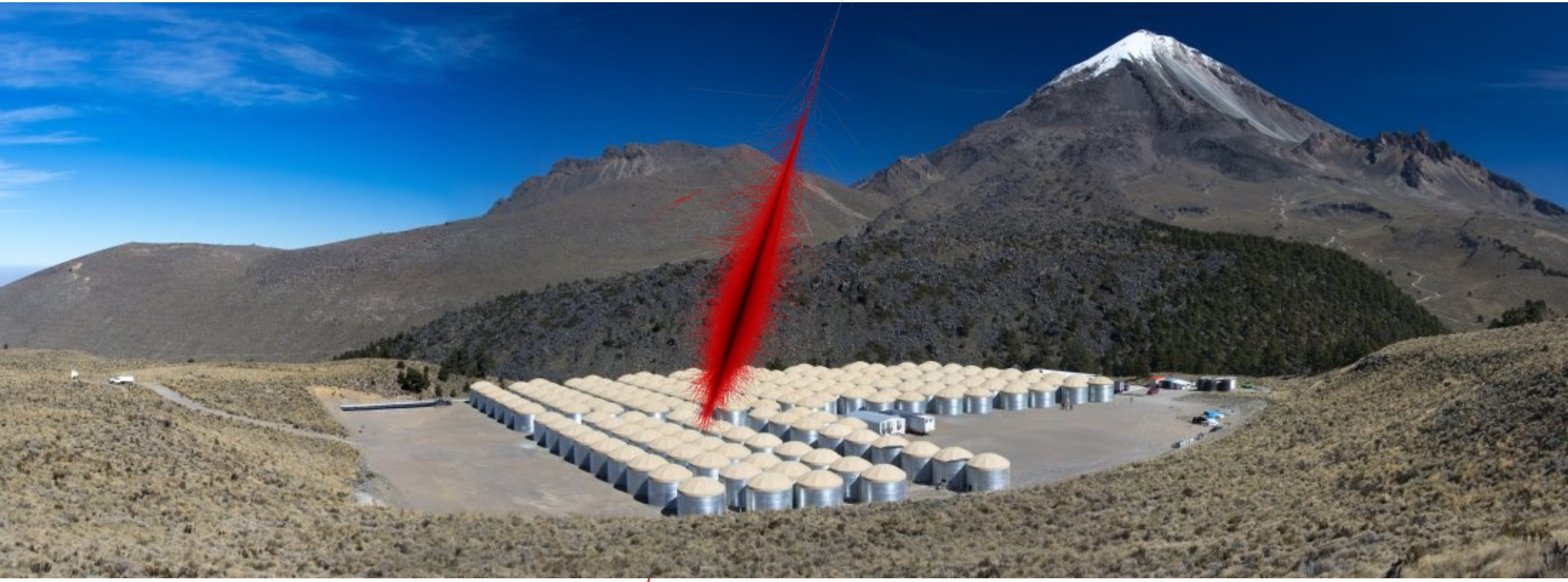
H. Zhou, H. Ayala

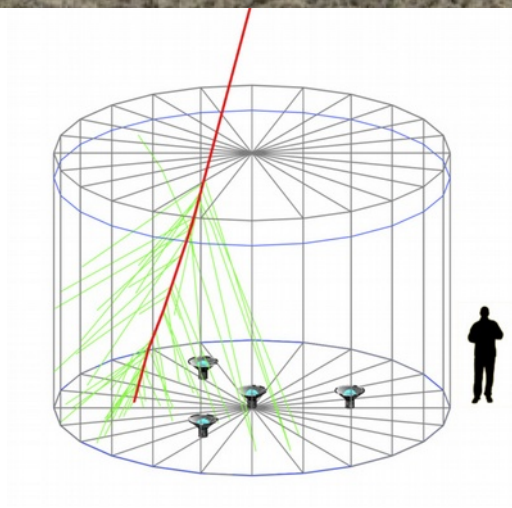
The HAWC Array

- **20,000 m^2** covered with water Cherenkov detectors (WCDs)
- **200,000 liters** of purified water **per tank**
- **1,200 PMTs** (900x 8" from Milagro + 300x 10" central high QE PMT)
- **300 WCDs** at completion, 200 tanks built, **125 WCDs operational now**
- Ongoing **data taking during construction** (started October 2012)

High Altitude Water Cherenkov



Detection of Cherenkov Light from secondary air shower particles

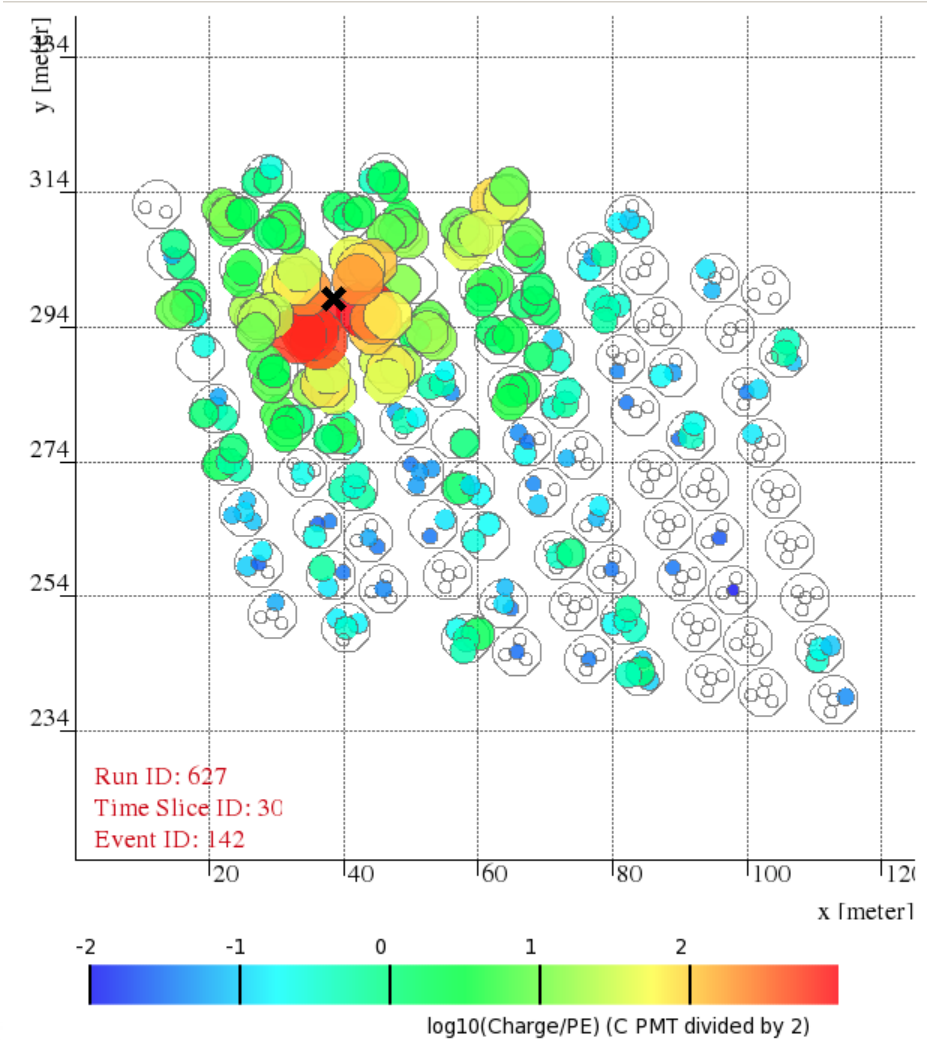


4 Hamamatsu Photo Multiplier Tubes (PMTs) in each tank
3x 8" PMTs
1x central HQE 10"

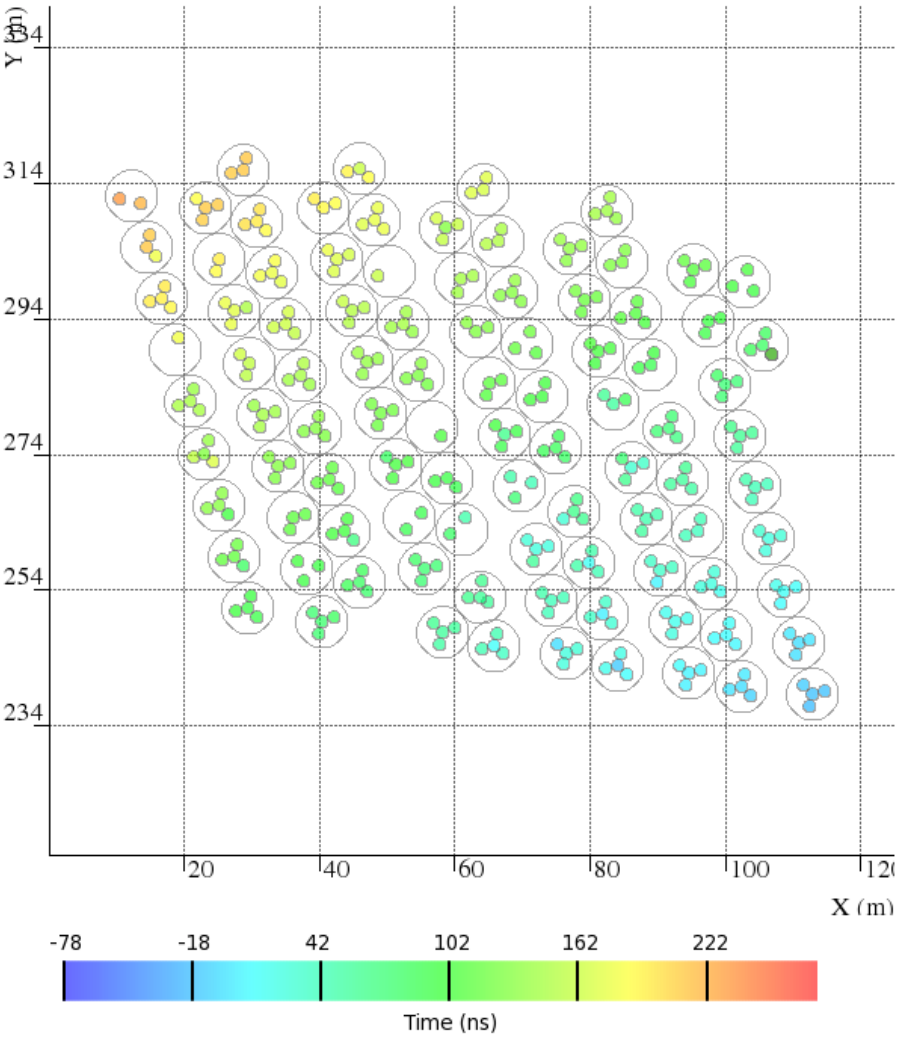
Air Shower Event

Reconstruction:

1) Locate **shower core** based on **charge distribution**



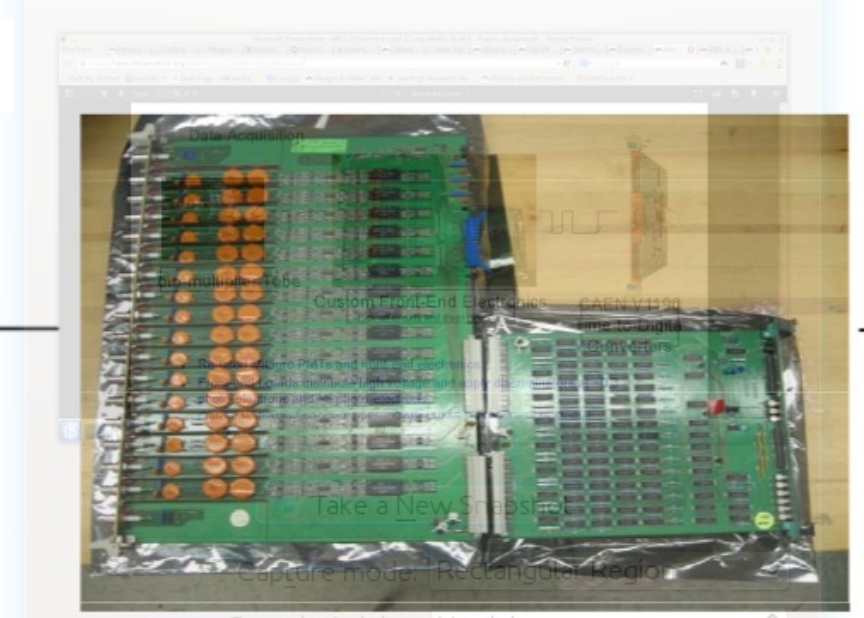
2) Fit **shower front** to photon **arrival times → angle**



Data Acquisition

Analog pulses are transmitted from the PMTs via the HV cables to the counting house.

Signal edge times are picked up via discriminators on FEBs and recorded in TDCs.



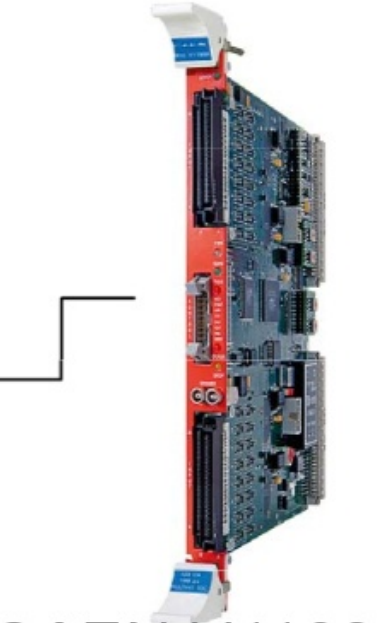


Photo-Multiplier Tubes (PMT)

Custom Front End Board (FEB) Electronics

CAEN V1190 Time-to-Digital Converter (TDC)

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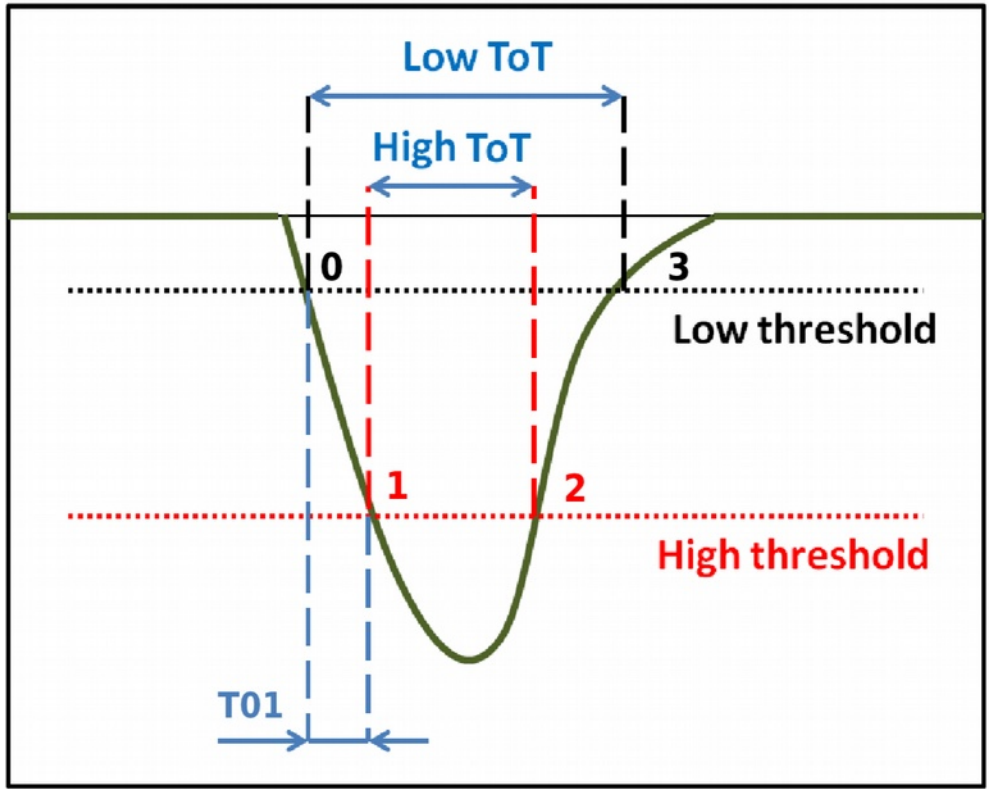
<u>Additional DAQ:</u>

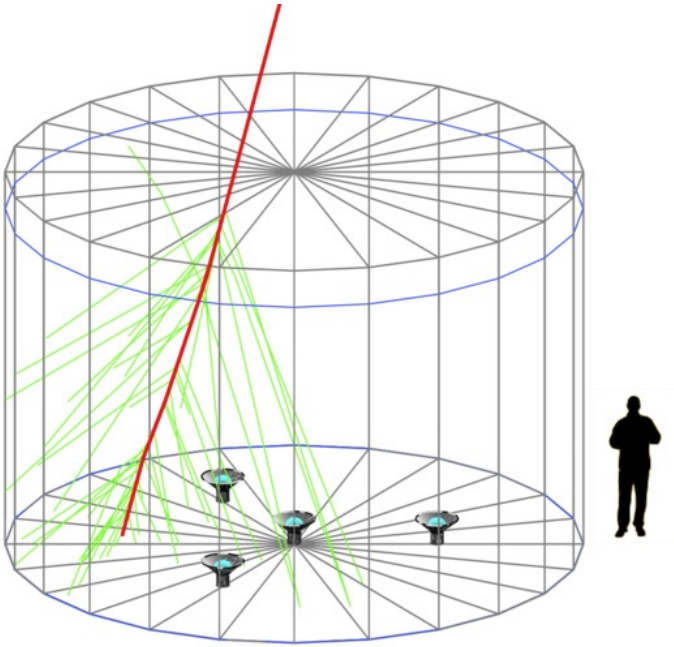
Scaler count rate for each PMT channel

PMT Signals

The main DAQ of HAWC measures only **Times over Threshold (ToT)** for each PMT hit.



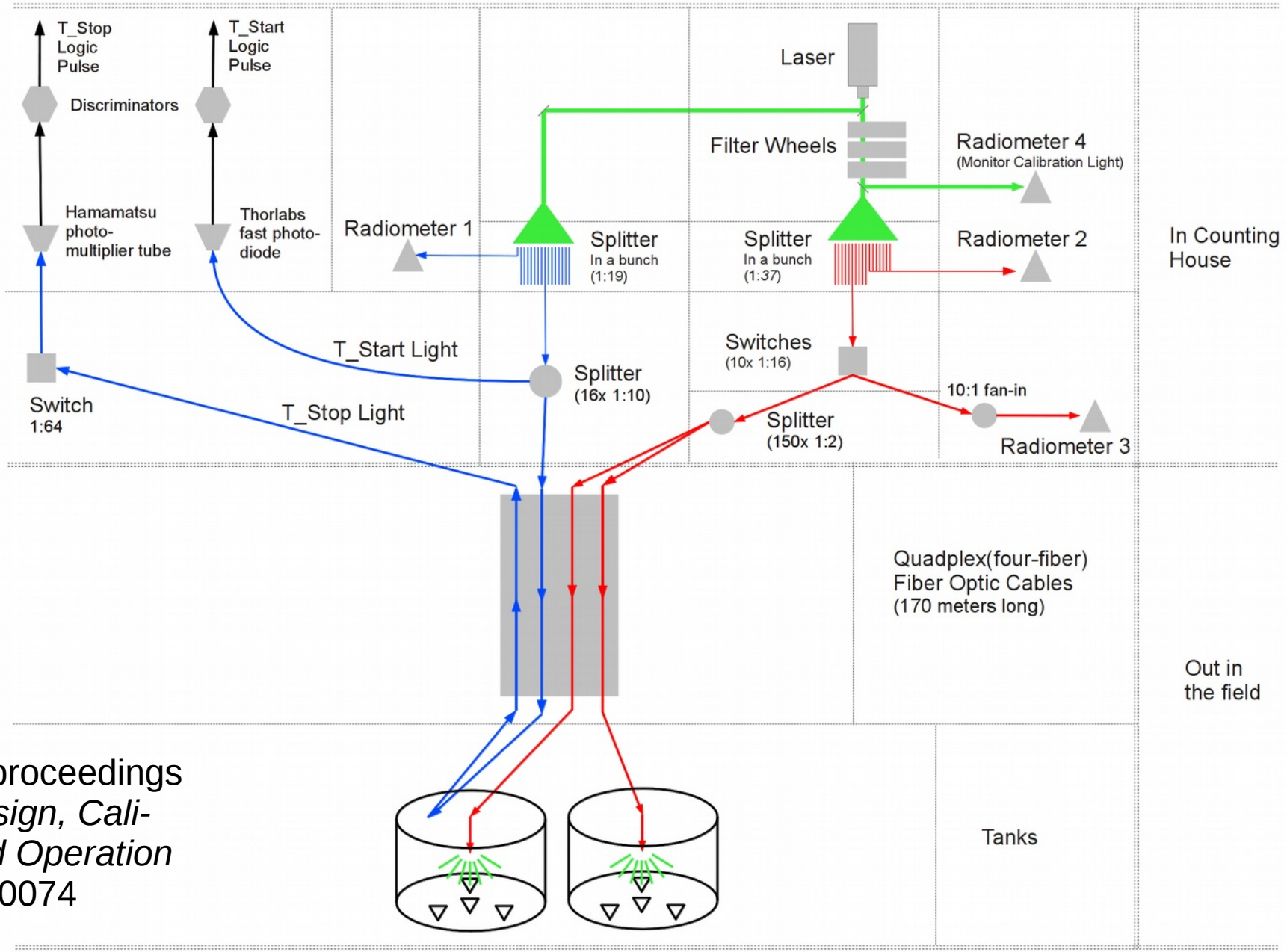
There is a **low** and a **high** **threshold**. Signals are recorded as **2-edge** (low threshold only) or **4-edge events.**



2 Calibration Tasks

1) **Charge Calibration**
   Translate ToTs into photo electron (PE) energies
2) **Timing or Slewing Calibration**
   Leading edge offset, depending on pulse width

Laser Calibration System



See ICRC proceedings
HAWC: Design, Calibration, and Operation
arXiv:1310.0074

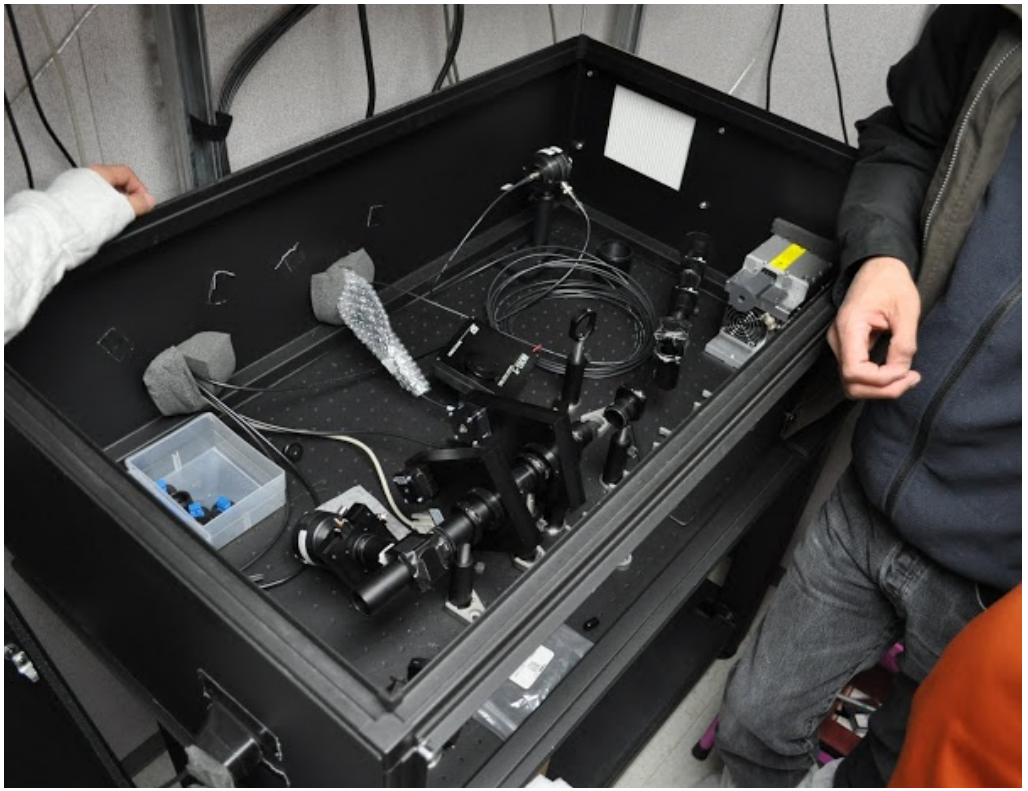
Laser Calibration System

Laser specs:

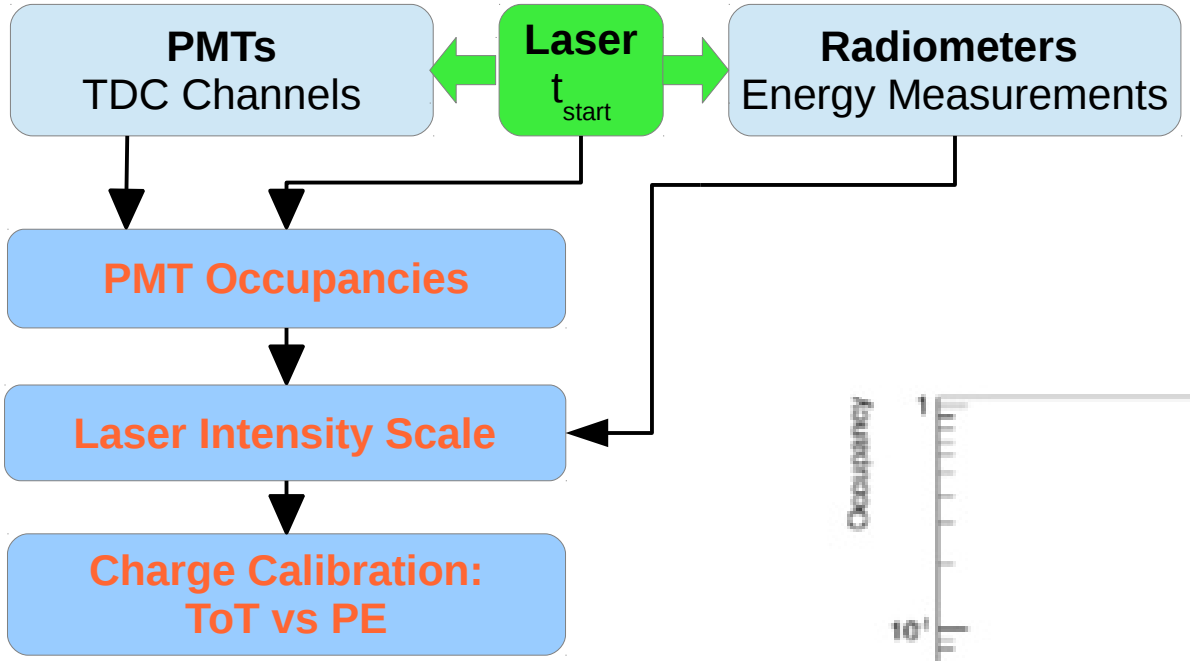
- Pulse width 300 ps
- Pulse intensity range (after fiber/diffuser) **from <0.1 PEs to ~10,000 PEs**

Calibration run:

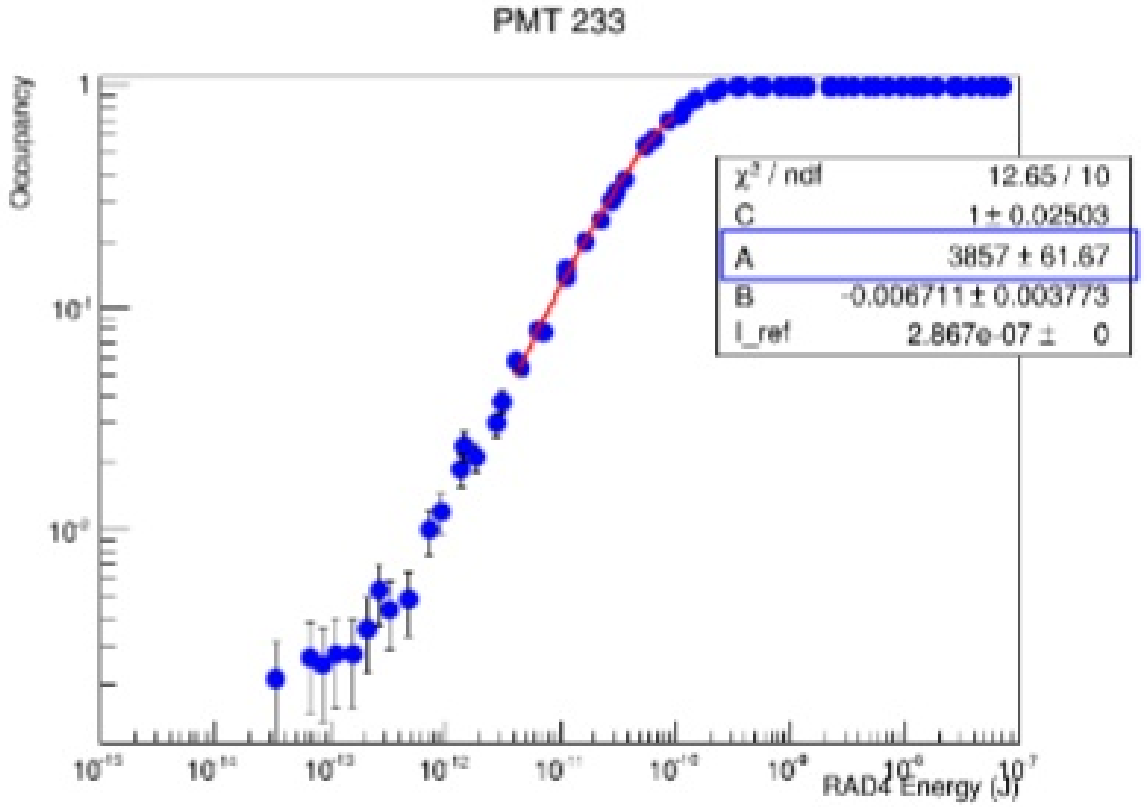
- Typically 68 intensity levels
- 2000 laser pulses at 200 Hz for each intensity
- **No interruption of data taking** exact trigger signals tag light-in-detector events, causing less than 1% dead time.



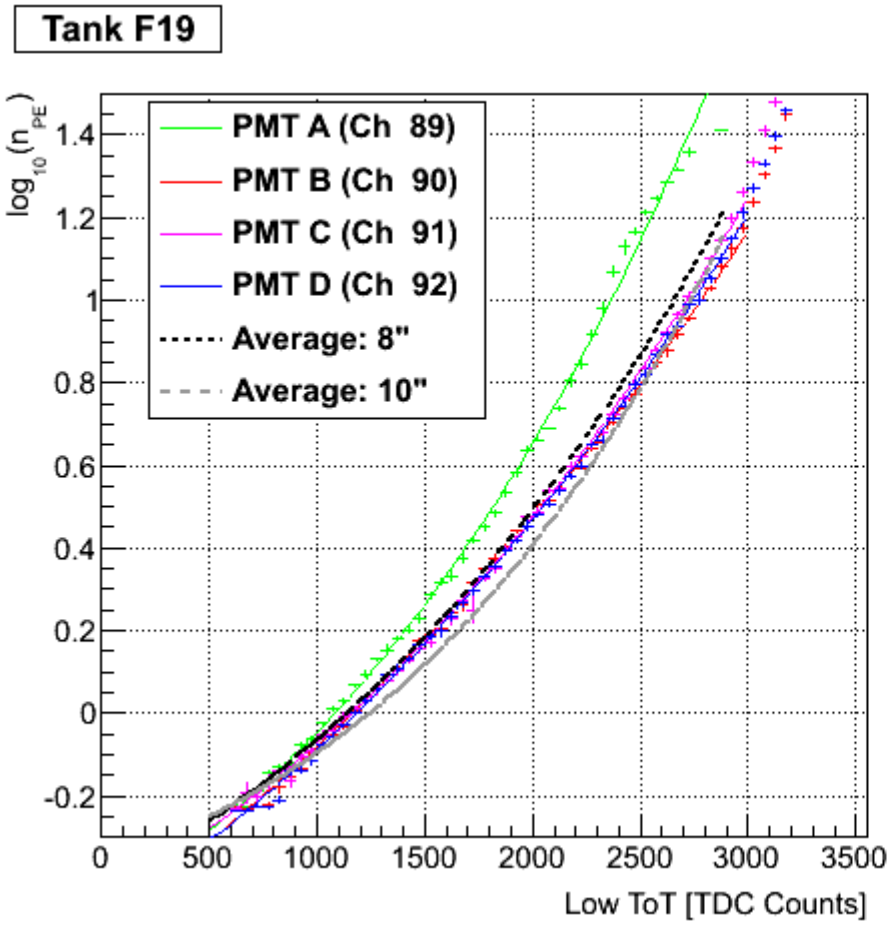
Charge Calibration

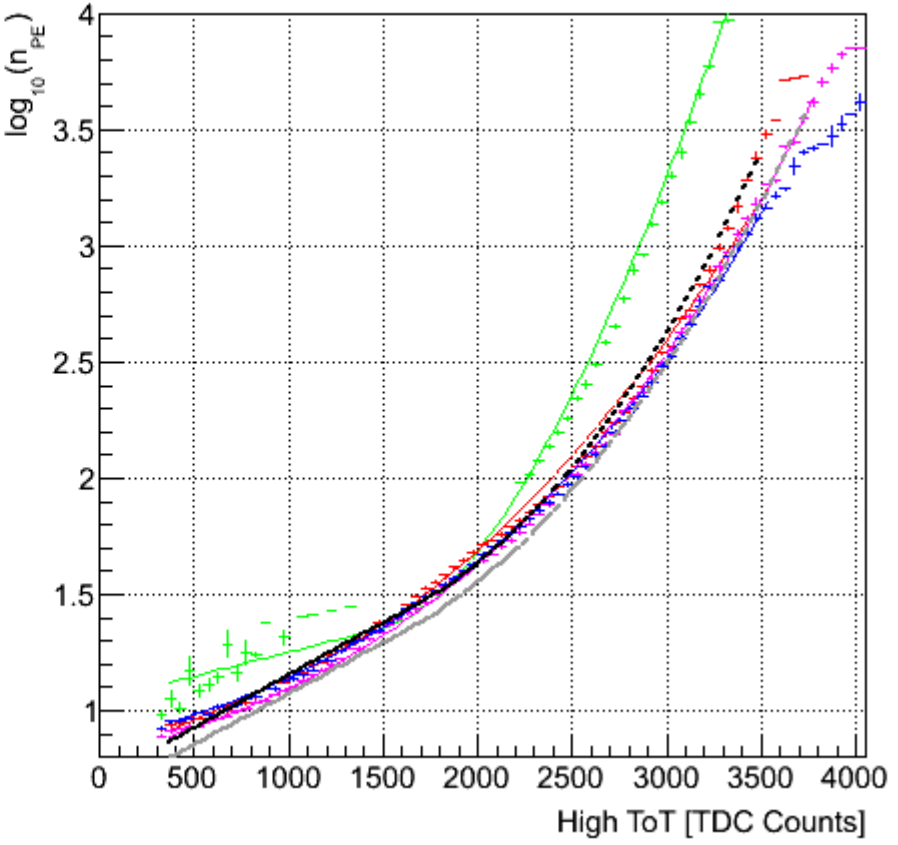


Poisson PMT occupancy response from ~ few PE hits provides absolute laser intensity scale



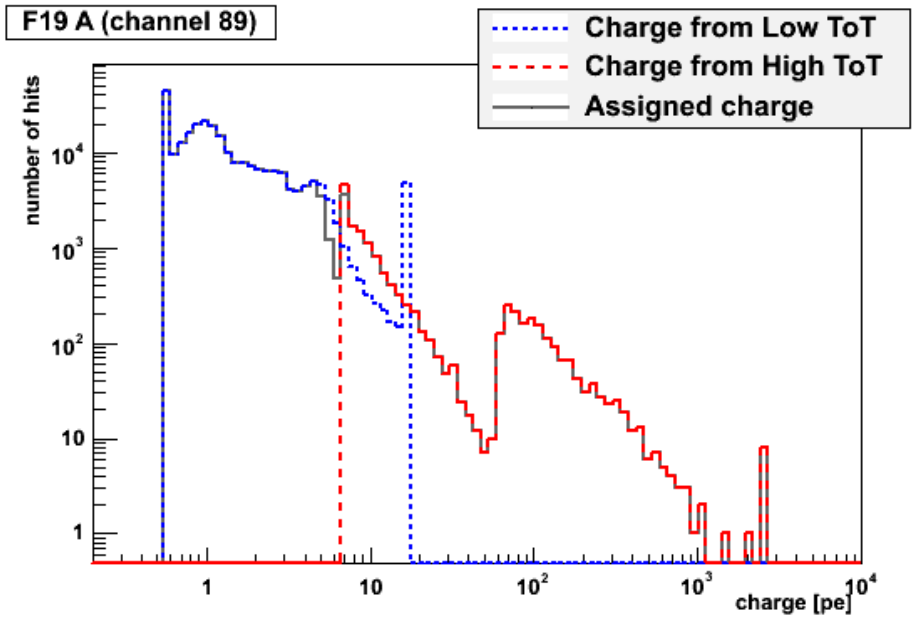
Charge Calibration Curves

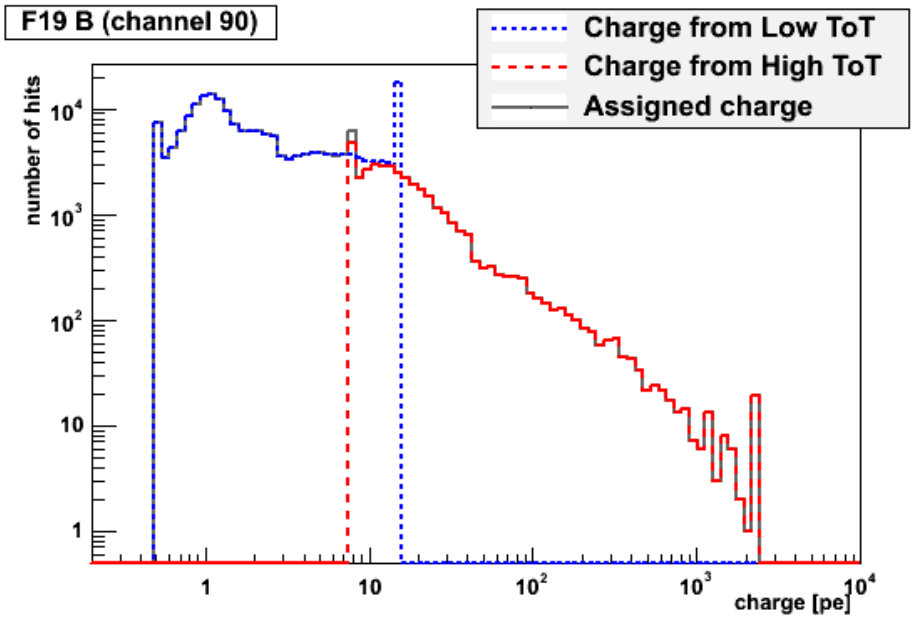


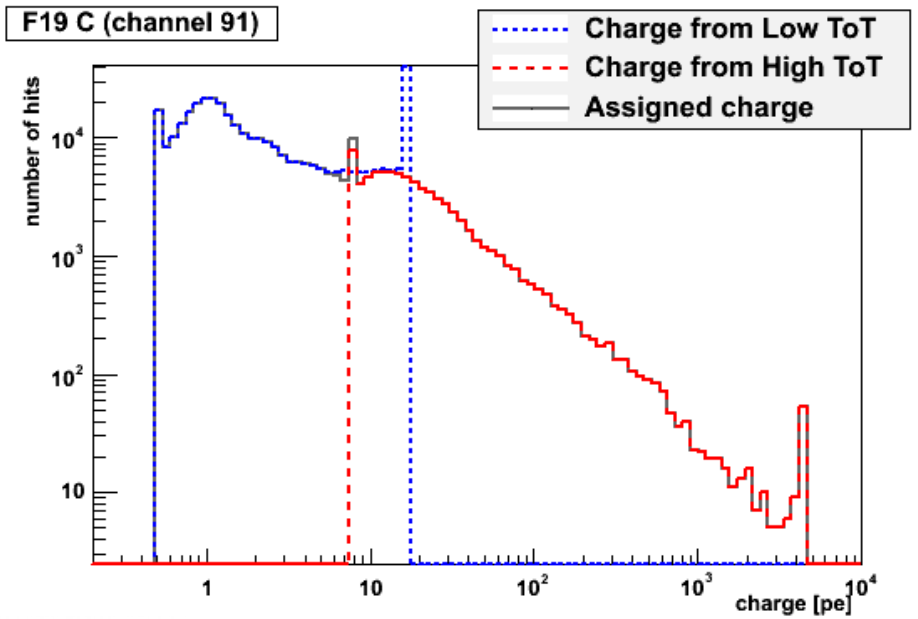


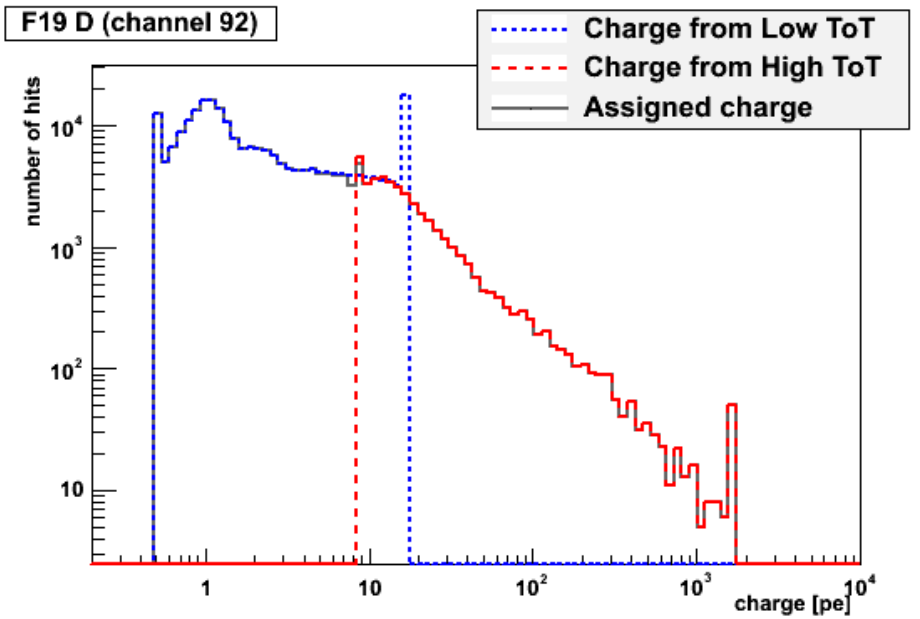
PMT ToT response can be mapped onto established laser intensities to yield **charge calibration curves**.

PMT Charge Distributions

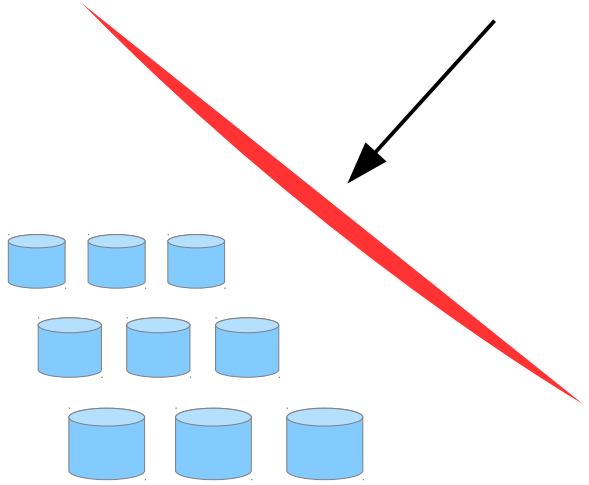




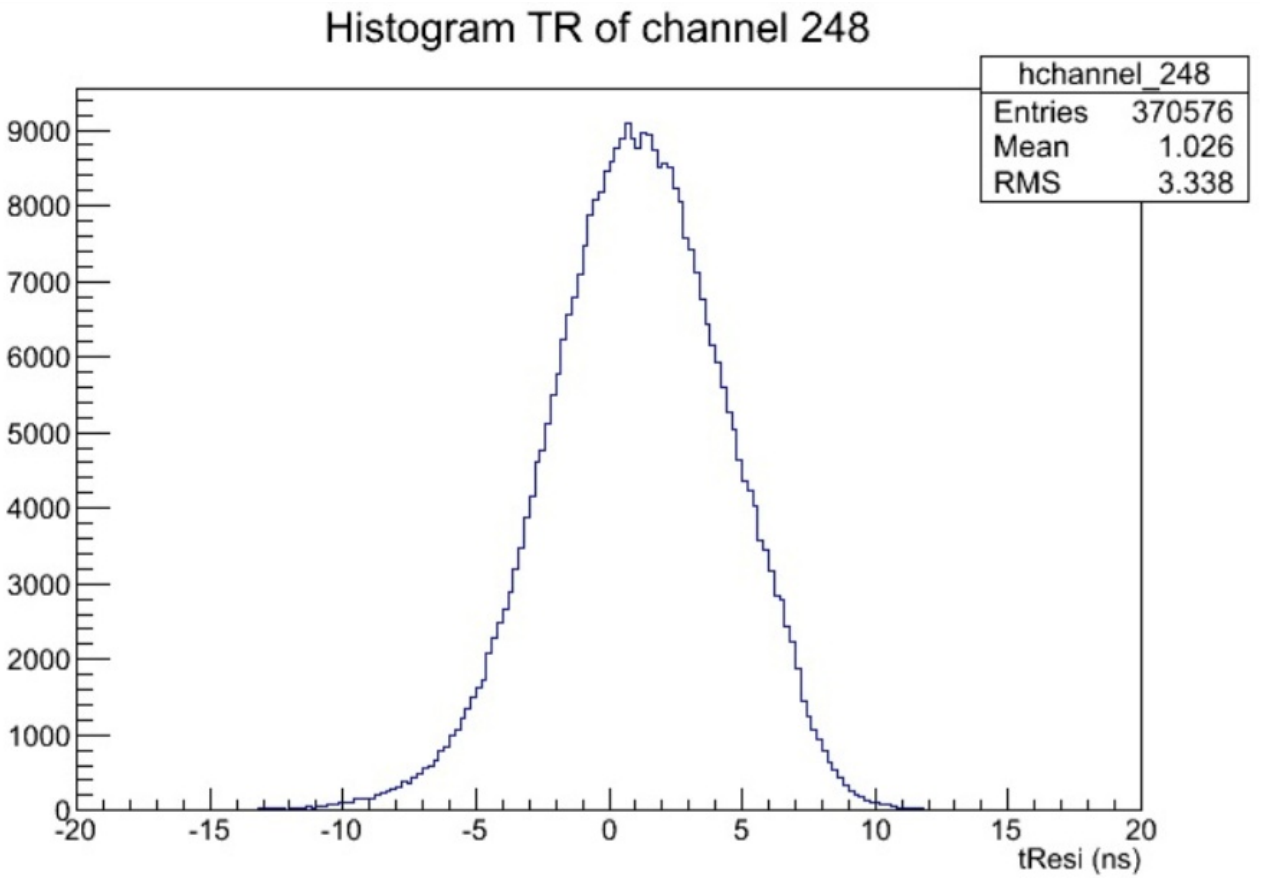




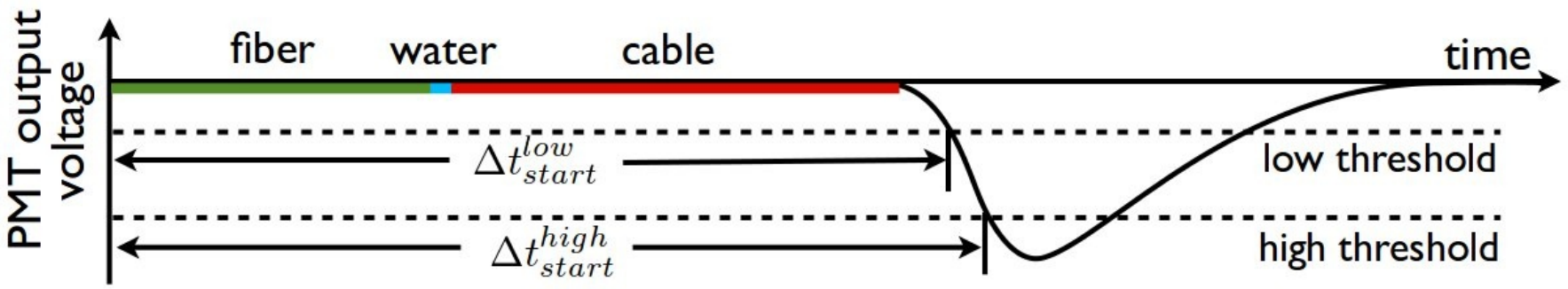
Timing Calibration



PMT hit time residuals relative to reconstructed shower front

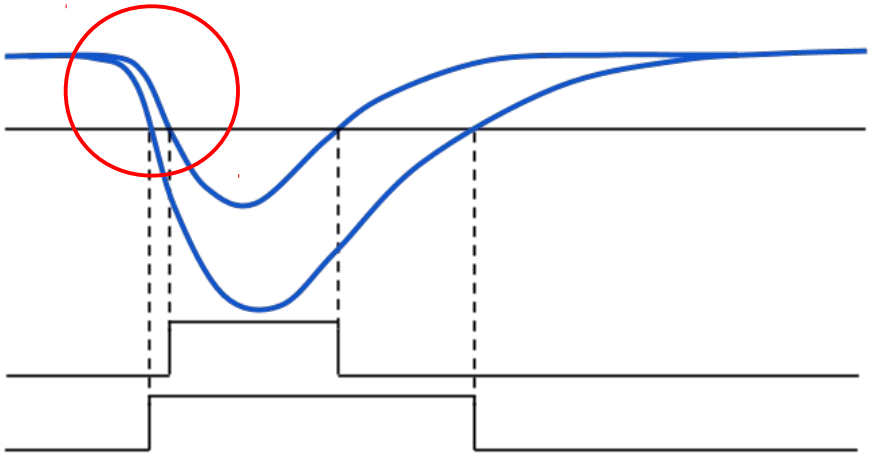


Timing Calibration

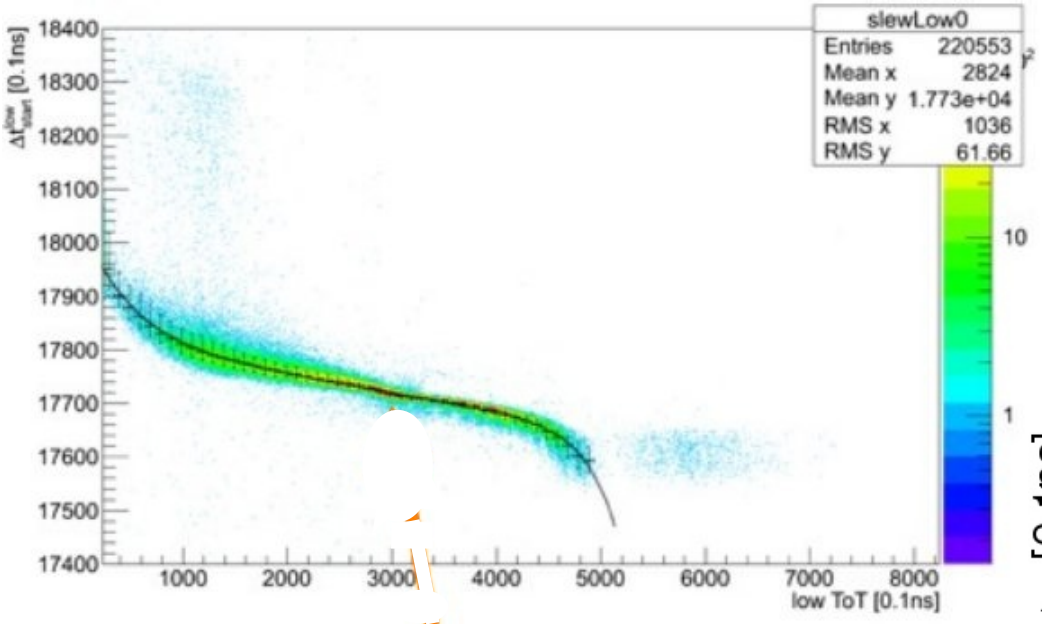


Time Pedestals:
Cable lengths, electronics and individual PMT characteristics introduce delays that can be measured with precise laser pulse timing.

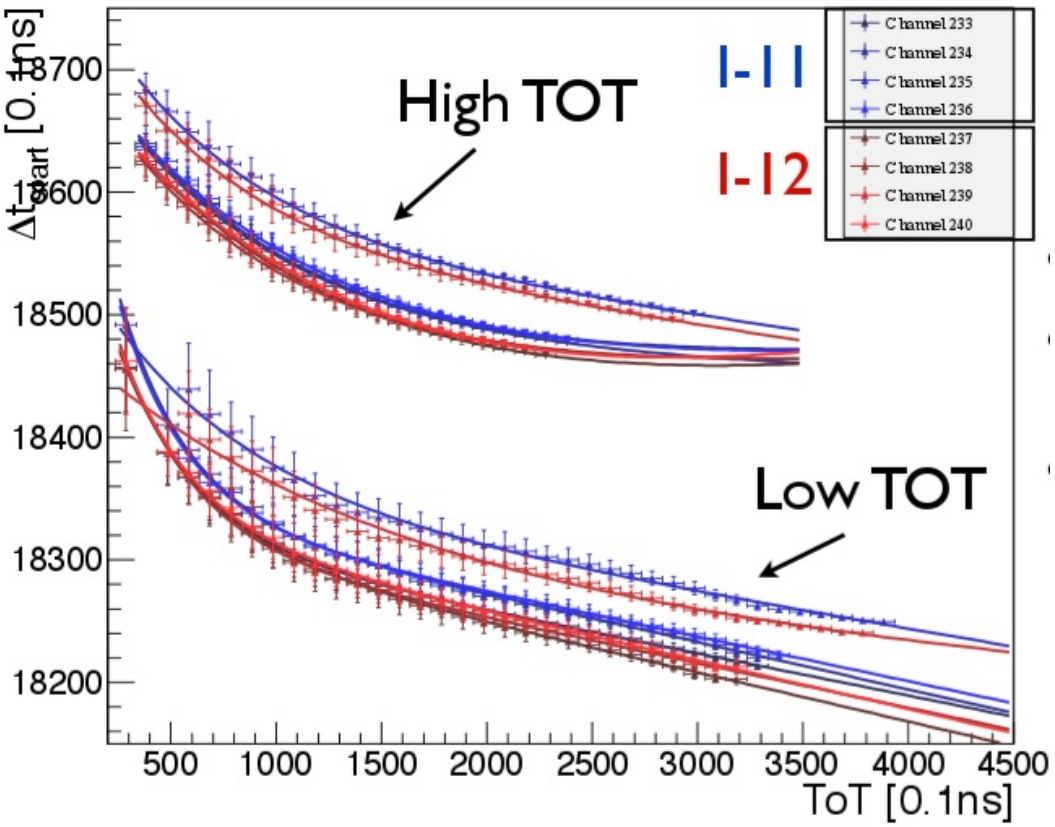
Slewing:
Threshold crossing delay
Depending on pulse amplitude



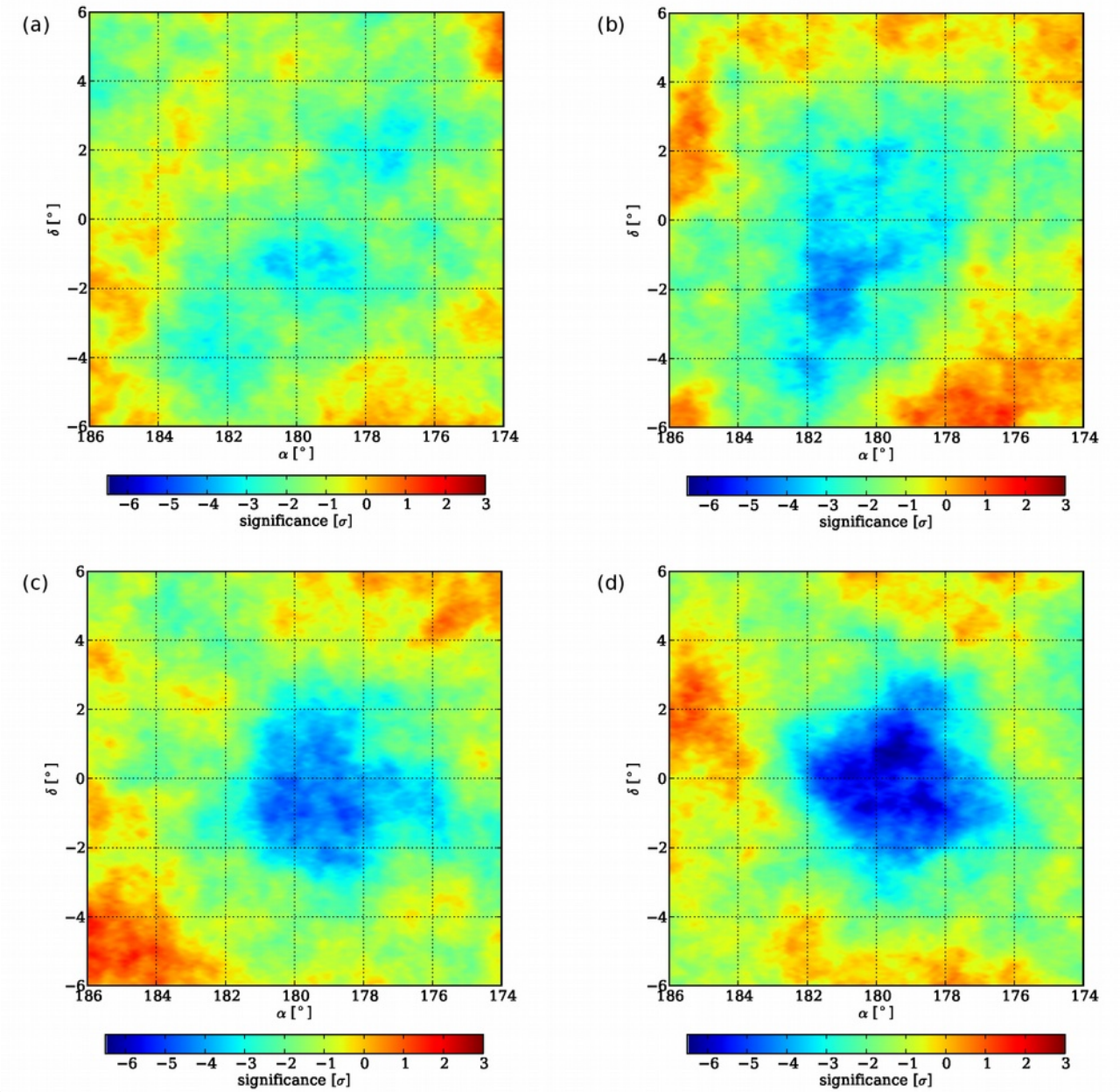
Slewing Calibration Curves



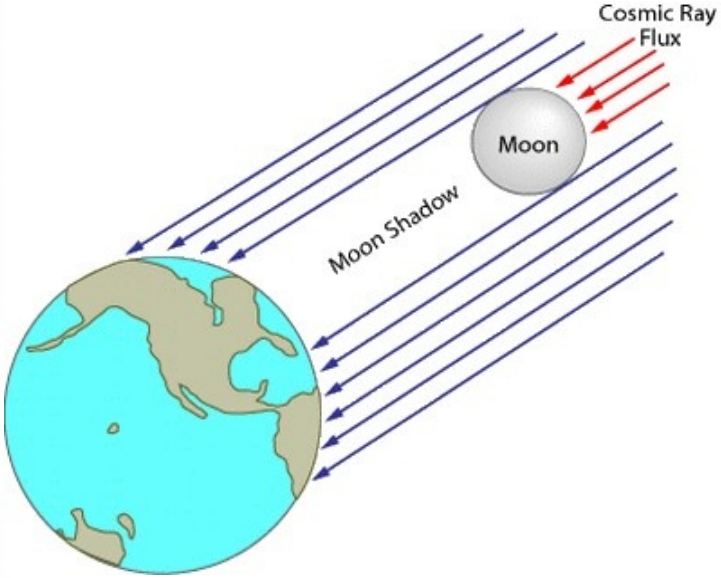
$$\Delta t_{start}(ToT) = e^{\frac{-ToT-p0}{p1}} + p2 - p3 * ToT$$



Calibration Performance

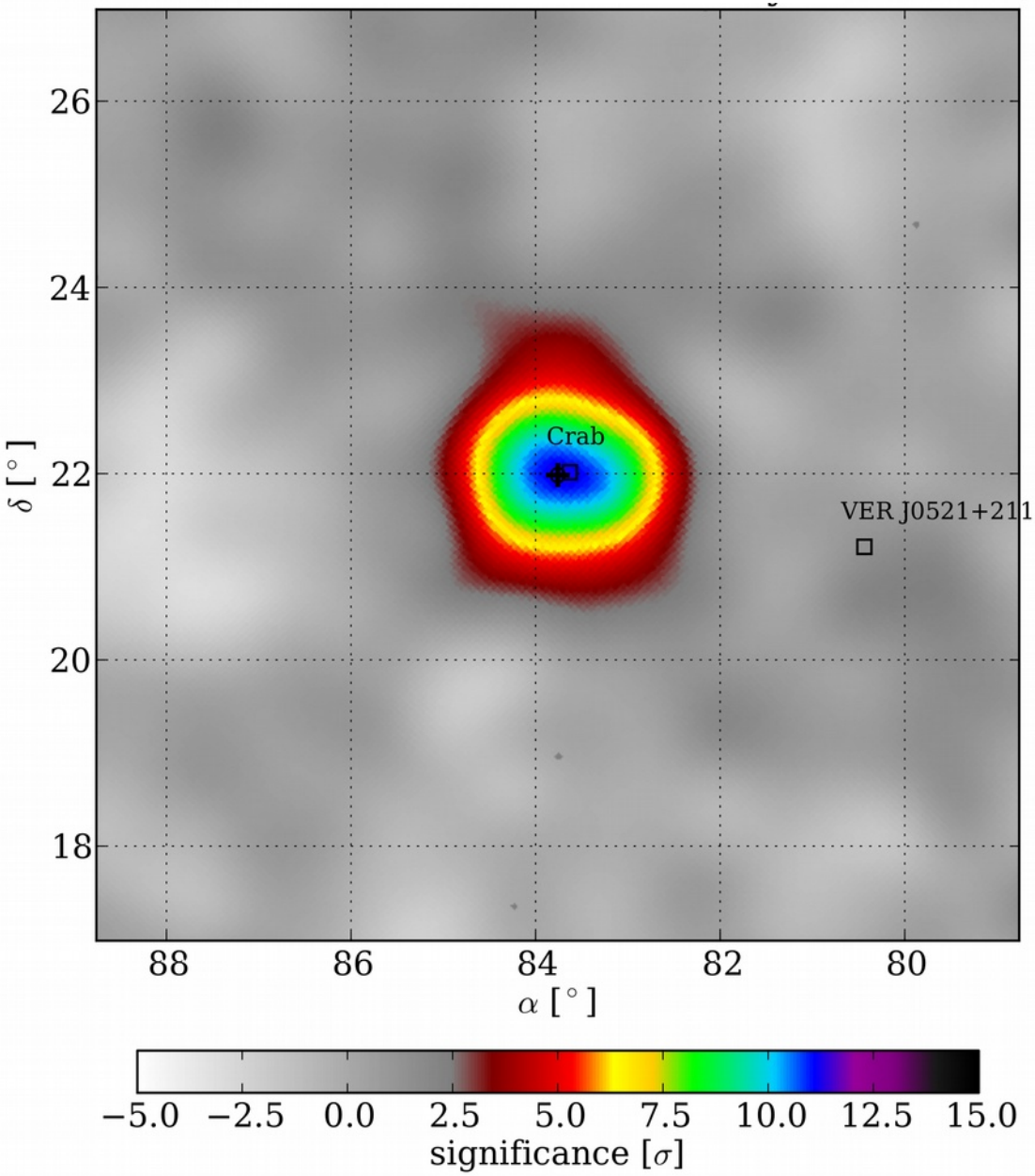


Limited amount of HAWC-30 moon data, taken over ~3 months



Summary

- **Cherenkov photons** from air shower particles are observed via PMTs and recorded as **time-over-threshold events**.
- A **laser system** provides calibration light in all tanks to **calibrate charge and timing response** for PMT hits.
- The system has been **operational for 1 year** and is crucial for shower reconstruction. Tanks are still being connected to the fiber network, thus improving future calibrations
- Alternative calibrations, e.g. via muon reconstruction, are being explored.



Thank you!